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SUMMARY REPORT ON CHARACTERIZATION OF STEEL SHIP PLATE

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PHYSICAL METALLURGY RESEARCH LABORATORIES
REPORT: MRP/PMRL 82-83(TR)

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by

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ABSTRACT

Steel plates from three Coast Guard ships and a bulk carrier have been characterized by composition, mechanical properties and toughness. The correlation of the conventional Charpy energy with the nil-ductility temperature varies by a factor of 5. However, the specific energy absorption or dynamic stress intensity determined from precracked Charpy specimens reduced the correlation factor to 1.7 or less.

INTRODUCTION

Five steel ship-plates were received from Transport Canada from the Coast Guard vessels Louis St. Laurent, John A. Macdonald, Camsell and the bulk carrier M.V. Arctic in continuation of the work being performed as part of the CANMET Marine Material Project (370072).

A plate from the Camsell and a plate from the M.V. Arctic contained a fracture face. Visual examination of these fracture surfaces indicated a brittle appearance in both cases. There was no evidence of a fracture origin in either plate.

This report presents the results of the mechanical properties, spectrocnemical analyses and toughness parameters of the five steel plates.

EXPERIMENTAL PROCEDURE

Tensile, Charpy impact and drop-weight specimens were machined with the longitudinal axis of the specimens in the plate-rolling direction and were located near the plate surface in the thickness direction. Notches were cut perpendicular to the plate surface in the Charpy impact specimens. Tensile specimens were 12.7 mm in diam with a gauge length of 50.7 mm.

Standard Charpy impact tests were conducted at different temperatures to establish impact energy transition curves for each steel plate. Additional Charpy specimens were fatigue precracked and dynamic fracture toughness tests were carried out at different temperatures, including the nil-ductility temperatures, using a Dynatup instrumented Charpy apparatus. Testing procedures were in accordance with ASTM standards.

RESULTS AND DISCUSSION

The five steel plates were reported to be of quality representative of the "Ordinary Strength Grades" such as those listed in ASTM A131-81a.

This is verified by the spectrochemical analyses and tensile test results shown in Tables 1 and 2 as well as the Charpy impact energies given in Table 3 at temperatures indicated in the relevant specifications.

Impact energy-temperature transition curves are shown in Fig. 1. Included in Fig. 1 are curves identified by solid lines depicting these relationships for plates tested previously (Report MRP/PMRL 80-50(TR)). The curves represented by the broken lines are the results of tests reported herein.

Standard Charpy energy values corresponding to the NDT temperatures ranged from 10 J to 49 J. The stress intensity factor (K_d) and specific energy W/A determined from precracked Charpy specimens are given in Table 4. The K_d values corresponding to the NDT temperatures ranged from 29.7 MPa.$m^{1/2}$ to 39.6 MPa.$m^{1/2}$ whereas the range of values for W/A at the NDT temperatures was from 10 to 18 J/cm^2. The variations in the aforementioned precracked Charpy parameters are reduced substantially when compared with the conventional Charpy energies.

The fracture sufaces of two plate samples cut from larger fractured plates from the M.V. Arctic and the Camsell respectively are shown in Fig. 2 and 3. The test plate (Fig. 2) from the damaged area in the vessel M.V. Arctic is shown by the circle in Fig. 4. Visual examination did not reveal any origins of fracture. However, the plate from the Camsell (Fig. 3) contained a white coating along one edge of the fracture face as denoted by the arrow. A microprobe examination of this coating and a sample of the coating on one surface of the plate were similar. The fracture surface was highly corroded precluding a detailed metallographic examination.

A second plate from the Camsell, Fig. 5, contained a short length of steel rod, 12.7 mm diam, inserted and welded into a plate cavity. The rod is shown in cross-section in Fig. 6. It was reported (letter Sept. 27, 1978, File 9562-07103, DSSS-Victoria) that temporary on-site repairs were made to the vessel in order that it could be towed with ice-breaking assistance. It would appear that the rod was used in these repairs.

SUMMARY AND CONCLUSIONS

1. The mechanical properties and spectrochemical analyses of the steel plates numbered 6, 7, 9 and 10 (Table 1) conform to specification ASTM A131-81a. Steel plate number 8, a replacement plate, meets the requirements of CSA Standard G40-21-1976.
2. Toughnesses have been measured by standard Charpy and pre-cracked Charpy tests. There is far less variation in toughness parameters when pre-cracked samples are used.

ACKNOWLEDGEMENTS

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Table 1. Steel composition (wt %)

Plate* No.	C	S	P	Si	Mn	Ni	Cr	Mo	V	Al	Cu	Nb	Grade ASTM A131-81a
6	0.15	0.013	0.008	0.23	1.05	<0.01	<0.015	<0.01	<0.005	0.03	<0.005	0.005	D-killed
7	0.16	0.022	0.006	0.25	1.03	0.02	<0.015	<0.01	<0.005	0.035	0.035	<0.005	E-killed
8	0.20	0.02	0.004	0.20	0.94	0.01	<0.015	<0.01	0.01	0.015	0.035	<0.005	CSA G40-21-76 38T norm. F.K.
9	0.14	0.013	0.019	0.21	0.67	<0.01	<0.015	<0.01	<0.005	0.01	<0.005	<0.005	D-killed
10	0.21	0.025	0.006	0.035	0.74	<0.01	0.02	<0.01	-	<0.005	0.050	-	A-semi-killed

*Plate identification

6 John A Macdonald (Replacement plate)

7 Louis St. Laurent

8 Louis St. Laurent (Replacement plate)

9 Camsell

10 M.V. Arctic

Table 2. Tensile test results

Plate No.	Thickness in (mm) approx.	U.T.S. ksi	U.T.S. MPa	Y.P. ksi	Y.P. MPa	Elongation in 2 in. (50 mm)
6	1 3/16 (30)	65.6	452	46.5	320	37
7	2 (50)	64.3	443	37.7	260	38
8	2 (50)	67.7	466	44.5	307	39
9	1 (25)	62.1	428	39.1	269	37
10	1 1/8 (30)	64.5	444	34.2	236	35

Table 3. Charpy V-notch results relative to specification requirements

Plate No.	T °C	W ft-lb	W J	ASTM A131-81a ft-lb	ASTM A131-81a J
6	-10	36	49	20	27
7	-40	41	56	20	27
8	-46	43	58	** 15	20
9	-10	72	97	20	27
*10	0	6	8	-	-

* Charpy V-notch tests not required for Grade A plate in thicknesses up to 2 in. (50.8 mm)

** G40.21-76

Table 4. Values of standard Charpy energy (W), precracked Charpy specific energy (W/A), and fracture toughness (K_d) at NDT temperature

Plate No.	NDT °C	W ft-lb	W J	W/A ft-lb/in^2	W/A J/cm^2	K_d ksi.in$^{1/2}$	K_d MPa.m$^{1/2}$
6	-20	15	20	56	11	27	30
7	-40	36	49	90	18	33	36
8	-45	35	47	68	13	36	40
9	-15	23	31	71	14	31	34
10	0	7	9	53	10	30	33

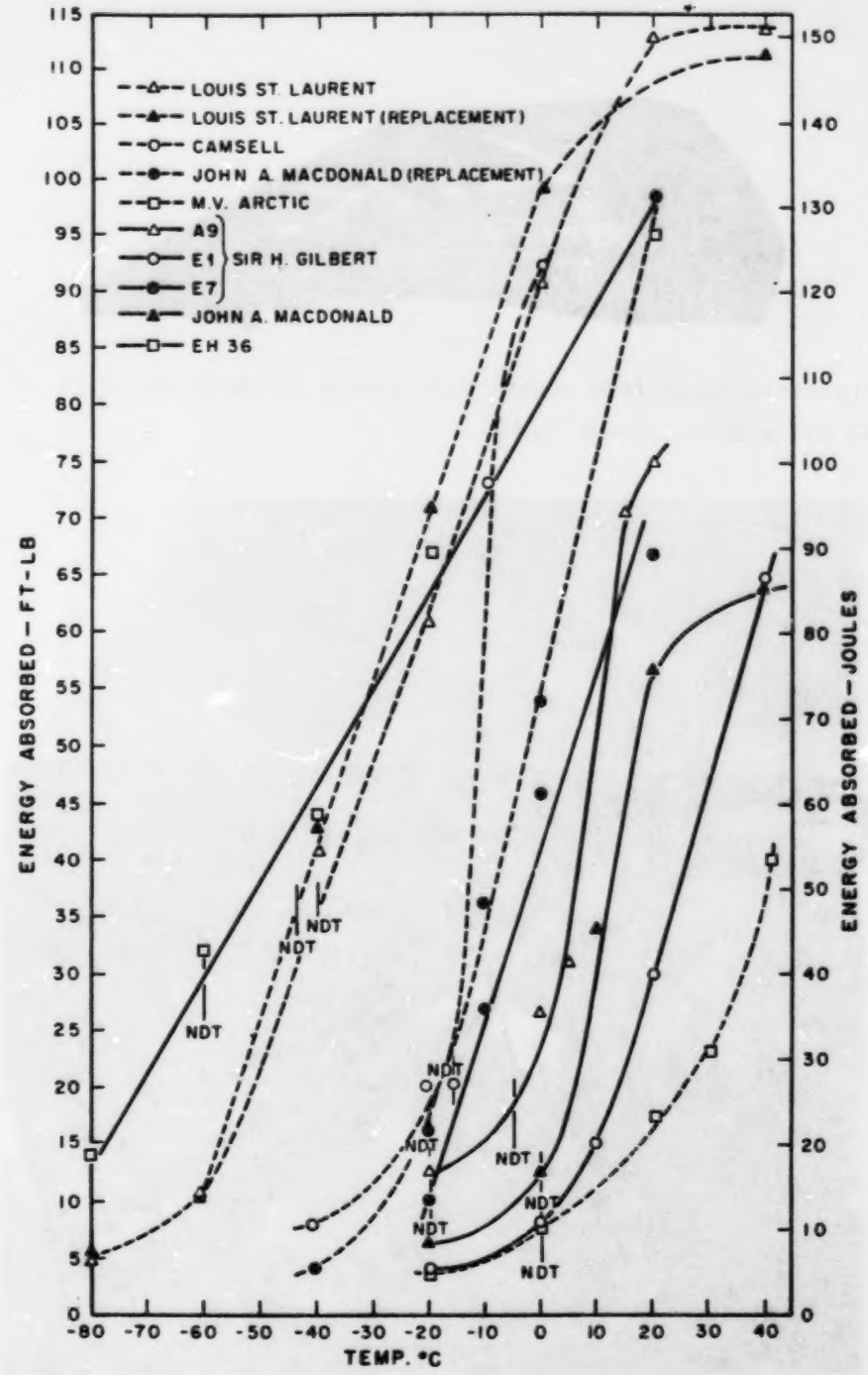

Fig. 1 - Energy-temperature transition curves developed from standard Charpy V-notch impact tests. Neg. 6767

Fig. 2 - Fractured plate from vessel M.V. Arctic (dimensions 30 in (76 cm) x 15 in. (380 cm) apprcx. (neg 3140)

Fig. 3 - Fractured plate from CCGS Camsell showing coating on fracture face (plate dimensions approx. (46 cm) x (30 cm). Neg. 6019

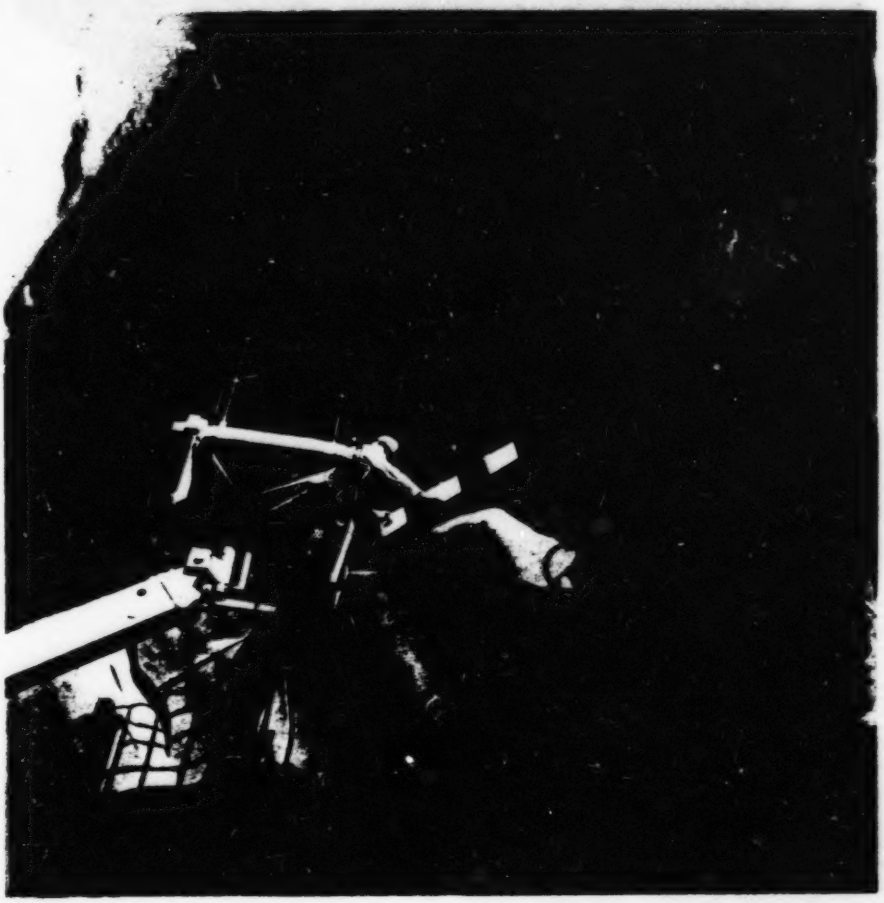

Fig. 4 - Damaged bow section in bulk carrier M.V. Arctic. Neg. 5791

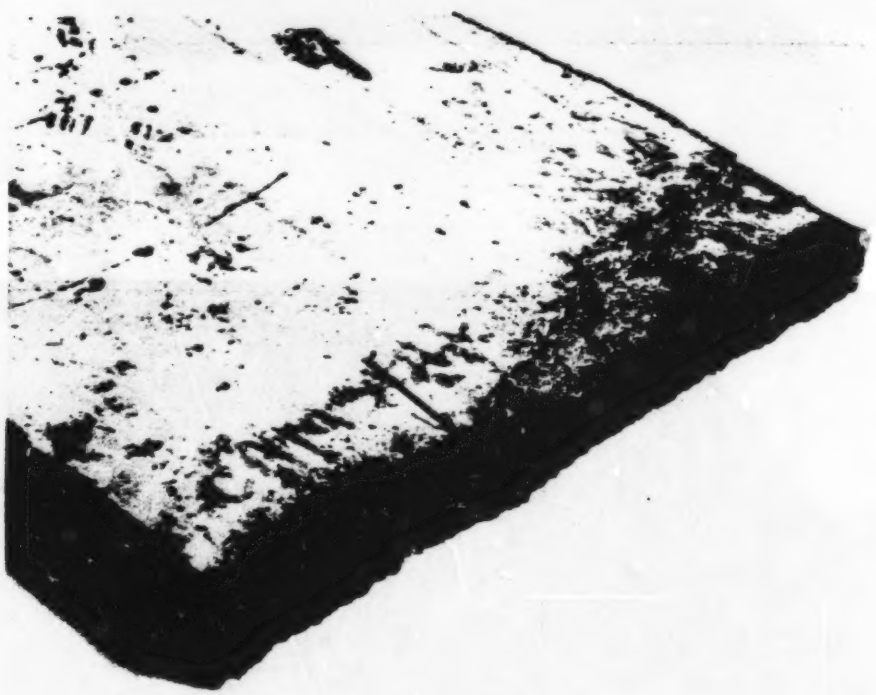

Fig. 5. Plate from CCGS Camsell showing 1/2 in. diam rod. (neg 6020)

Fig. 6. Cross-section of rod shown in Fig. 5. (neg 6769)